THE UPPER PALAEOZOIC ROCKS IN THE NEIGHBOURHOOD OF BOOROOK AND DRAKE, N.S.W.

By A. H. Voisey, M.Sc.

(Plate viii; one Text-figure.)

[Read 29th July, 1936.]

The object of this paper is to describe the rocks outcropping in the Drake and Boorook Districts in north-eastern New South Wales and to place the fossil zones in their correct positions in the sequence.

A short stay was made at Rivertree during February, 1934. Tabulam and Drake were visited during June and July, 1934. In January, 1936, the Boorook and Crooked Creek fossil beds were examined and their relationship to the Drake volcanic formations was established beyond doubt.

The geological sketch-map (Pl. viii) is not accurate in detail, but serves to indicate the fossil localities, and, roughly, the areas occupied by the series into which the strata have been divided. The mapping of the units within the series has unavoidably been left until a later date. Mr. E. C. Andrews (1908) said of the area: "It is a difficult area to map accurately, *i.e.*, in which to supply a connected sequence of geological events. Instead of containing several strong lines of rock junctions, whose succession in time might thus be readily grasped, it consists of a mass of insignificant and overlapping lava flows, sandwiched in with which are certain fossil beds. Dense jungle growths are common, which still further complicate mapping work."

He, however, did map the rocks around Drake, and his map may be considered typical of the whole area occupied by the volcanic beds.

Previous Literature.

E. C. Andrews (1908) detailed the history of the area, reported the discoveries of fossils and described the past mining activities. He also discussed the general characteristics of the ore deposits and their probable origin. This report, so far as the writer is aware, is the only record of geological field-work in the area which comes within the scope of this paper. J. B. Jaquet (1896) reported on the Lunatic Goldfield but did not deal with the general geology. Many references to Drake are to be found in literature, notably by Browne (1929), David (1932), Richards and Bryan (1923, 1924), Sussmilch (1935) and Walkom (1913). These writers have confined themselves to discussions based upon the work of Andrews (1908).

Stratigraphy.

The Upper Palaeozoic strata between Boorook and Tabulam are bounded by granite on the east, west and south. Both granite and sediments are overlain in places by Jurassic rocks belonging to the Clarence Series.

The older beds have been divided into two main Series, the Emu Creek Series which is, in all probability, Carboniferous in age, and the Drake Series, which is probably Permian. The latter has been subdivided into a Lower and an Upper Division. The Lower consists chiefly of lavas, agglomerates and tuffs, and

the Upper of tuffs, mudstones, and occasional lava flows, and characteristically possesses prolific fossil horizons.

Andrews (1908) observed that the Drake mudstones and tuffs (Upper Division) were younger than the volcanic beds (Lower Division), but he referred the latter to two distinct periods, "an older consisting mainly of rhyolites and a younger mainly of andesites".

While no definite divisions are likely to hold throughout the area, owing to the discontinuity of most of the beds, an arbitrary boundary has been fixed between the Lower and Upper Divisions. This boundary is indicated on the map and sections, but it must be emphasized that it is only approximate. It does not mark any great change in the nature of the deposits, but separates a zone which is prolific in fossil remains from one in which fossils are less numerous owing to the greater amount of volcanic material, chiefly lava, which makes up the sequence. No fossils appear to have been found in Andrews' older volcanics (lower part of Lower Division).

The relationship between the Emu Creek Series and the Drake Series has not been established beyond doubt, but the dark mudstones and tuffs belonging to the former seem to dip beneath the Drake volcanic rocks in the south-western corner of the Parish of Jenny Lind and also in the northern part of the Parish of Antimony. However, the outcrops are poor, and insufficient time was available to determine this point, important though it is. In spite of this admission of doubt, from field evidence alone the greater age of the Emu Creek Series may be accepted with slight reservation. The palaeontology is sufficient to clinch the matter.

The northward extent of the Emu Creek Series was not investigated far beyond Emu Creek, but the beds continue at least to Pretty Gully.

The following table shows the succession of beds which has been established:

Age.	Name of Series.	Rock Types.	Estimated Thickness in Feet.	Correlation.
Recent		Alluvium and creek gravels.		
Jurassic	Clarence Series.	Conglomerates, sandstones, and shales with fossil wood.		Walloon Series.
Permian	Drake Series. Upper Division	Fossiliferous mudstones and tuffs, with some lava flows in lower portion.	2,000 +	Silverwood Fault-Block Series, and Lower Bowen Volcanics.
	Lower Division	Lavas, agglomerates, breccias and tuffs, with some fossiliferous beds.	5,000 +	
Carboniferous ..	Emu Creek Series.	Dark rhythmically-bedded mudstones and tuffs with lighter-coloured sandy beds.	Very thick, but no estimate made.	Neerkol (?) Series.

Carboniferous.

Emu Creek Series.

It must be made clear that the tuffs, sandstones, and conglomerates belonging to the Emu Creek Series are lithologically and palaeontologically quite distinct from the rocks belonging to the Drake Series, and must not be confused with them. Andrews (1908) appears to have recognized this, for he says: "The fossiliferous slates at Drake had been observed to be gently folded only. Towards Jump-Up, however, the strata possessed a vertical dip; thence to Pretty Gully the dip fell to 40°. Thus a tangential thrust from the east was suggested, unless the Drake rocks proper should be decidedly younger than the Pretty Gully series."

The name "Pretty Gully Series" would be retained for the Jump-Up beds but for the fact that the present writer did not visit Pretty Gully, and does not feel justified in using this name. Moreover, Andrews did not define the Pretty Gully Series further, and did not discuss the rocks. Hence the name "Emu Creek Series" will be used for the beds outcropping around Jump-Up Hill, although it is probable that the Pretty Gully beds could be correlated with them.

The lowest units of the series which were examined outcrop near the junction of Kangaroo Creek and Emu Creek, and consist of dark-grey indurated tuffs, fine in grain and rhythmically bedded with tuffaceous sandstones and occasional thin bands of conglomerate. All members of the series are hard and, in many places, intensely mineralized.

The fine-grained tuffs grade into dark grey mudstones and all the members bear witness to the fact that they are water-sorted; the pebbles in the conglomerate bands are well rounded and water-worn. The coarser beds are generally lighter in colour than the mudstones and tuffs, and are subordinate to them.

A horizon with remarkably prolific Fenestellidae outcrops on a spur between Kangaroo Creek and Emu Creek. The whole slope is strewn with fragments of rock crammed with the polyzoans. The material is a very hard, silicified light-blue to greyish-blue mudstone, highly impregnated with pyrites throughout. Its appearance is far different from the Fenestellidae mudstones of the Drake Series.

Only one specimen of *Spirifer striata* was found amongst the *Fenestella* and crinoid stems. My attention was drawn to this horizon by Miss Dorothy Smith and Mr. Arthur Smith of Cheviot Hills Station.

Probably overlying this Fenestellidae horizon by a couple of hundred feet is the Jump-Up Hill fossil horizon from which Andrews and the writer have collected a number of forms. These will be listed and discussed later.

The fossils are preserved in mudstone and fine-grained sandstone, probably tuffaceous, and are most abundant in the road cuttings ascending the hill. Many can be obtained in Jump-Up Creek. The beds are not nearly so indurated or so mineralized as those in the vicinity of the Fenestellidae horizon, but they are nevertheless very hard. The fresh sandstone is bluish-grey in colour, but weathers to a light-brown. The rocks are somewhat disturbed in the vicinity of Jump-Up Hill but the overlying beds continue with a general westerly dip of about 60° for at least 3 miles up Emu Creek. Although faulting may have caused some duplication, there is no doubt that a great thickness of rhythmically-bedded mudstone and sandstone overlies the Jump-Up horizon.

Near the boundary of the parishes of Antimony and Callanyn, the creek exposes a peculiar agglomerate. It contains irregular fragments of fine bluish-grey tuff set in a tuffaceous matrix. This rock is interbedded with tuffs similar to the fragments it contains.

It is in this locality that lava flows occur and seemingly overlie the west-dipping Emu Creek beds. Although an examination was made the actual contact was not found.

Permian.

Drake Series.

(*a*) Lower Division.

The magnificent suite of volcanic rocks outcropping around Drake has been partly described by Andrews (1908). Detailed petrological work on the numerous rock types is most desirable, but the writer had not the time necessary for this, so has very little to add. Andrews (1908, p. 11) writes: "The lavas of the Drake district present a difficult problem as regards detailed sequence of events. They are studies in minutiae. Frequently, within the limits of a 10 or 20-acre block, as many as a dozen rock sub-types may be found."

He has divided the volcanic beds into two groups: "(*a*) One productive of whitish to grey felsites, purple and green lavas, tuffs and breccias, and practically devoid of stratification planes. (*b*) A younger one, productive of blue and purple agglomerates, breccias, lavas and tuffs deposited on a sinking sea floor."

This division is upheld from a descriptive point of view, but there seems to be no need to make the break very significant. Andrews, himself, suggests that his older series may represent (1) the actual sites of small vents or (2) masses thrown out of neighbouring small vents. No evidence contributing to the problem was collected, but the detailed map given by Andrews is sufficient to show that his opinions are backed by much field-work and are worthy of consideration.

No records of fossils from the older volcanic beds have been found, and this is hardly surprising, since they are made up of so much lava and agglomerate. Stratification is much more marked in the younger volcanic beds than in the older, and the marine fossils found in the tuffs and mudstones between lava flows and agglomerates show that most were laid down under water.

Andrews submits the following list of fossils from Drake:

Martiniopsis subradiata var. *deltoidea* Eth. fil.
Fenestella sp.
Strophalosia jukesii Eth. fil.
Productus undatus ?.
Spirifer stokesi Konig.
Zaphrentis sp.
Stenopora (dendroid form).
Trachypora wilkinsoni Eth. fil.
Hyalostelia.
Entolium.
Modiola.
Aviculopecten (new sp.).
Orthoceras.

Knowing that most of the beds around Drake belong to the Lower Division of the Drake Series, one feels justified in considering that these fossils may be referred to the younger volcanic portion of the sequence.

Fragmental fossil remains, including *Monilopora*, *Trachypora*, Fenestellidae, crinoid ossicles, and Spiriferaceae, were found in the tuffs and mudstones outcropping in Girard Creek, about three miles west of Cheviot Hills Station. These sediments are interbedded with most spectacular agglomerates containing angular to sub-angular blocks, chiefly of felsite lava, up to nearly two feet across.

Several thousand feet of these tuffs and agglomerates, with occasional lava flows, are exposed between Cheviot Hills and Crooked Creek. At the top of this succession is a unit, about 200 feet thick, which, though an agglomerate at the base, passes upwards into a green tuff resembling an andesitic lava. The gradual change in texture from fragments more than a foot across to minute particles in the top-most portion may be traced.

Overlying this horizon is a mudstone bed full of *Trachypora wilkinsoni*. This has been taken as the base of the Upper Division of the Drake Series in this locality.

Andrews described the Girard Creek beds thus: "In many cases a conglomerate bed will contain numerous angular and subangular blocks; or, again, a conglomerate mass will pass gradually into an agglomerate. Here, commingling of two processes is evidenced—in shallow water agglomerates have been primarily thrown out, where probably the sea reduced the mass to a conglomerate; oftentimes, however, the imposition of fresh agglomerate deluges checked the process of pebble formation. Redistribution with partial to complete rounding by waves of breccias and agglomerates intermittently discharged from volcanoes is most probably the origin of the great majority of such rock masses."

Another section of the younger volcanic beds which was measured at Boorook ascending the hill between the ruins of the treatment plant on the Cataract River and the old Boorook township site, gives the following sequence:

(In descending order.)	Approx. thickness in feet.
Trachyte and trachytic tuff	100
Agglomerate	50
Trachyte	40
Felsite and felsite-breccia	100
Grey felsite	30
Felsite-breccia	30
Pink felsite	40
Agglomerate	20
Green trachyte	100
Volcanic breccias and agglomerates	200
Grey trachyte	100
	810

These are overlain by the Upper Division of the Drake Series. The Cataract River has only cut down as far as the grey trachyte, so that the underlying beds are not exposed in this locality. According to Andrews, however, the Cataract flows through felsite-breccias and lavas for miles downstream and the banks are high and almost impassable.

It is not possible to give a reliable figure for the thickness of the volcanic beds. A most conservative estimate, based on the section from Crooked Creek down Girard Creek to a point about two miles north-east of Cheviot Hills Station, is about 5,000 feet. The lower members of the Series have not been located definitely, though the lavas in the north-east of the Parish of Antimony must be among them. It is of importance to determine whether the volcanic rocks are underlain by marine fossil beds and also a *Glossopteris* horizon, as is the case at Silverwood.

(*b*) Upper Division.

Fossiliferous mudstones, tuffs and quartzites inter-bedded with breccias, agglomerates and occasional lava-flows follow conformably upon the main volcanic beds of the Lower Division of the Drake Series. The diminution in the amount of volcanic material and the greater development of the fossiliferous marine sediments are the characteristic features of this portion of the sequence. Eventually, the volcanic beds pass into mudstones which have a thickness exceeding 1,000 feet. As the rocks overlying the mudstones were not examined, it is not known whether the vulcanism continued after the deposition of these beds.

A specimen section measured down a spur leading into Sawpit Gully, Boorook, is as follows:

(Descending order.)	Approx. thickness in feet.
Massive dark-grey mudstones	1,000
Fossiliferous mudstones (Zone "D")	200
Felsite-lava	20
Coarse tuffs and breccias	100
Mudstones and cherts (Zone "C")	100
Felsite-breccias and coarse tuffs	100
Coarse breccia	10
Coarse tuffs with quartzite bands (Zone "B")	100
Fenestellidae mudstone (Zone "A")	20
Agglomerate	10
Fenestellidae mudstone (Zone "A")	50
Breccias and coarse tuffs	100
	1,810

The above thicknesses are approximate only and the units vary greatly throughout the district. The fossils collected from each bed will be given, but it is probable that most of the forms range throughout the above section. Collecting could only be carried on for a very short time, and numerous additions will be made to the lists when further work is done.

Immediately overlying the breccias and tuffs which form the basal unit of the above section is a band of calcareous mudstone crammed with fossils, chiefly Fenestellidae and crinoids. This is Zone "A" and contains *Zaphrentis* sp., *Martiniopsis subradiata* and *Spirifer* sp. (F36370–1 Australian Museum Collection); *Trachypora wilkinsoni* and *Monilopora* cf. *nicholsoni* appear to occur low down in the Upper Division in the Crooked Creek locality, but the sequence was not examined in any detail there.

The Fenestellidae mudstone is bluish-grey in colour when fresh, and is very tough. During decomposition it becomes buff-coloured and friable. The rock is made up of layers of fossils alternating with sediment. Weathering gives a concertina-like appearance to the outcropping blocks. An agglomerate with included rock fragments up to two inches across splits the Fenestellidae mudstone and the overlying bed is similar to that below (Zone "A").

Fossils are present, even in the coarse tuffs which follow, but, in the main, are fragmental, except in the quartzite and mudstone bands which are interbedded with these. They are mainly pectens and are so numerous that, in places, the quartzite is entirely made up of shells which have been replaced by silica. They include *Deltopecten subquinquelineatus* McCoy sp., *Aviculopecten sprenti* Johnston, and *Aviculopecten englehardti* Etheridge and Dun. *Fenestella* sp., *Protoretepora ampla* Lonsdale (?) and crinoid stems are also present in Zone "B" (Specimens F36367–9, Australian Museum Collection).

Felsite breccias and tuffs overlie the pecten horizon and then comes a most prolific fossil bed, a calcareous mudstone (Zone "C") containing:

Aviculopecten englehardti Eth. and Dun.
Aviculopecten cf. *flexicostatus* Mitchell.
Aviculopecten sp.
Productus (?) *brachythaerus*.
Taeniothyris subquadrata.
Crinoid stems.
Zaphrentis sp.
Fenestella sp.
Stenopora tasmaniensis Lonsd. (?).
Myonia carinata Morris.
Myonia (?) *corrugata* Fletcher.
Martiniopsis subradiata.
Strophalosia cf. *gerardi* King (?).
Strophalosia cf. *jukesi* Eth.

(Specimens F36344–F36366 Australian Museum Collection.)

Strophalosia is one of the commonest fossils in this zone and certain sections of the beds are made up almost entirely of this shell. In some parts the dendroid *Stenopora* is dominant and in others, *Fenestella*.

Coarse tuffs with fragmental fossils follow, and above these a felsite-lava flow outcrops.

On top of the felsite is a calcareous mudstone band (Zone "D") containing:

Monilopora cf. *nicholsoni* Eth.
Trachypora wilkinsoni Eth. fil.
Crinoid stems.
Fenestella sp.
Astartila sp.
Calyx plate of crinoid (*Cyathocrinus*?).
Strophalosia gerardi.

(Specimens F36329–31, F36335–43 Australian Museum Collection.)

The two corals are most numerous and they were used in tracing the bed along the ridge for about a mile, as they could be seen from a distance in the fragments of rock strewn over the surface. The lowest 200 feet of the mudstone, which makes up the rest of the section, contain numerous fossils, mainly corals, but the higher beds are practically devoid of them—only a few crinoid ossicles being found. The mudstone becomes less calcareous and more massive and compact. It is a dull black in colour and very fine-grained, for the most part, but is slightly more sandy in its lower portions. This sandy rock is lighter in colour, but has a blotchy appearance owing to the presence of dark irregularly-shaped inclusions. After several hundred feet, through which there is some variety in texture and colour, the mudstone becomes more uniform and apparently devoid of lamination and bedding planes. It is rather cherty and some harder parts give rise to falls in the creeks running west from the hills, but generally outcrops are poor. The beds are easily traced because they decompose to a characteristic yellow soil containing fragments of the crumbling rock.

This mudstone represents a complete change in the nature of the sedimentation. All through the underlying beds volcanic material is the main component right to the lowest part of the Drake Series that was examined. There is no important structural break, however, as the tuffs may be seen to pass upwards into the mudstone and fossils similar to those in the tuffs ascend well into the unit.

Fossils have been obtained in the hills bordering the granite for several miles north of Boorook. They also occur on the eastern side of the Cataract River and at Red Rock, where Mr. E. C. Andrews collected *Aviculopecten englehardti*. Between Crooked Creek and the stock route, the following forms were obtained:

Crinoid stems (*Phialocrinus*?).
Trachypora wilkinsoni Eth. fil.
Zaphrentis gregoriana De Kon.
Monilopora cf. *nicholsoni* Eth.
Cladochonus cf. *tenuicollis* McCoy.
Aviculopecten englehardti Eth. and Dun.
Fenestella sp.
Spirifer sp.

(Specimens F36324–8 Australian Museum Collection.)

These come from similar beds to those at Boorook as described above. Andrews (1908) records these additional types from somewhere along Crooked Creek:

Stenopora (small dendroid form).
Fenestella fossula Lonsd.
Fenestella internata Lonsd.
Fenestella sp.
Protoretepora (n. sp.).
Penniretepora grandis McCoy (De Kon.).
Hyalostelia.
Productus subquadratus Morris.
Martiniopsis subradiata Sby.
Spirifer vespertilio G. Sby.
Aviculopecten squamuliferus Morris.
Aviculopecten elongatus McCoy (De Kon.).
Stutchburia compressa Morris (?).

These fossiliferous beds undoubtedly continue for many miles to the north into the Rivertree District. It will be interesting to see whether the *Eurydesma cordata* recorded by Andrews from that locality comes from strata which can be correlated with some part of them.

Plumbago Creek Series.

Limestone, interbedded with hard slates and cherts, outcrops beside Plumbago Creek, just north of the point where the main road between Tabulam and Drake crosses the stream. The general strike of the series is north-north-west and the dip is west-south-west at about 60°. The invading granite cuts obliquely across the strike.

The limestone has been marmorized by the adjacent granite and no fossil remains were identified from it. The other sediments have been converted to hornfelses in places and are hardened elsewhere. Black slates contain fossils resembling *Pachydomus* but not definitely determinable. Breccias and tuffs related to those found around Drake are present, so it is probable that the Plumbago Creek Series will be connected in some way to the Drake Series. It has been kept separate because no limestone was found anywhere else and the northward extensions of it and the associated rocks were not followed far enough to connect them with any known beds.

Jurassic.

Clarence Series (Walloon?).

The Clarence Series between Tabulam and Casino consists of conglomerates, grits, sandstones and shales with plant remains. A basal conglomerate is well exposed by the road cuttings just west of Tabulam Bridge. The water-worn pebbles are arranged in lenticular bands in sandstones and grits. Much of the material may be identified, as it has been derived from the Upper Palaeozoic rocks.

The beds appear to be estuarine in origin. This belief is strengthened by the fact that numerous fossil tree-trunks were found in the overlying sandstones and grits to the east of Tabulam. Their occurrence is reminiscent of those at Warwick, Queensland, and it is possible that both are on the same horizon.

The age of the series is probably Jurassic and equivalent to the Walloon Series of Queensland. There has been an overlap of these beds on the lower members of the Mesozoic suite (David, 1932).

Intrusive Rocks.

The Granites.

The map (Plate viii) shows that the Upper Palaeozoic rocks are intruded by granite both to the east and west of Drake. The eastern mass is overlain by the Clarence Series, but the western forms the high plateaus of New England. The granite makes poor outcrops around Boorook Station, and only the aplitic dykes which traverse the main rock were examined. One such dyke is found near the Station yards.

More than twenty different phases of the granite were collected from the Stanthorpe and Rivertree Districts (D.R. 3339 to D.R. 3358). For further details with regard to the New England Granites, see Andrews (1903).

Palaeontology.

Emu Creek Series.

Andrews (1908) records the following fossils from Jump-Up Hill:

Strophalosia, sp. ind.
Productus subquadratus Morris.
**Spirifer* cf. *lata* McCoy.
Spirifer sp. nov.
Spirifer cf. *strzeleckii* Morris.
**Reticularia* cf. *lineata* Martin.
*Fenestellidae.
Aviculopecten cf. *mitchelli* Eth. fil and Dun.

(* Carboniferous type.)

The above were considered by Mr. W. S. Dun to be a mixture of Upper Marine and Lower Marine forms.

The writer collected two sets of fossils, one being given to the Australian Museum and the other to the University of Sydney. From the first, Mr. Fletcher has identified the following forms:

Cladochonus tenuicollis McCoy (?).
Strophalosia gerardi King (?).
Spirifer striata.
Spirifer pinguis (?).
Spirifer vespertilio.
Reticularia lineata.
Fenestella sp.
Stutchburia cf. *compressa.*
Aviculopecten ptychotis McCoy sp.
Aviculopecten cf. *pincombei* Mitchell.
Aviculopecten sp.
Phillipsia collinsi Mitchell.
Crinoid stems.

(Specimens registered F36372–F36379 Australian Museum Collection.)

Mr. Fletcher adds the following note:

"In the Jump-Up Hill beds, two pygidia and a thorax of *Phillipsia* cf. *collinsi* Mitchell were identified, with *Spirifer striata* and *Spirifer pinguis*. These are Carboniferous forms and when taken with the Carboniferous types recorded by Mr. E. C. Andrews, it would appear that the facies of the Jump-Up Hill beds would be rather Carboniferous than Permian. In the same beds *Stutchburia compressa* is found, but this genus probably extends into the Carboniferous. *Aviculopecten ptychotis* is also a Carboniferous species."

From the second collection, Dr. Ida Brown recognized the *Phillipsia* and *Cladochonus tenuicollis* as Carboniferous forms and showed the collection to Dr. F. W. Whitehouse, who has kindly supplied this information: The fossils belong to "a fauna equivalent to that found in the Neerkol Series of Queensland. From that fauna few species have been described. The types of spiriferids, productids and fenestellidae agree well with the Queensland types.

"In the collection the following genera are represented: *Cladochonus, Fenestella, Pustula, Spiriferina, 'Spirifer'* (spp. mult.), *Schizophoria, Retzia* (?), *Modiomorpha, Aviculopecten* and *Phillipsia.*

"The Neerkol Series is known in Queensland at Stanwell, Cannindah and Mt. Barney."

He is also of the opinion that the fauna is newer than the *Amygdalophyllum* horizon.

It is generally agreed, therefore, that the Jump-Up Hill horizon is of Carboniferous age. Mr. Dun's view that the beds were Permo-Carboniferous was probably influenced by the collections from adjacent areas occupied by the Drake Series.

Exact correlation of the Emu Creek Series with other areas will have to be made later by those acquainted with the Queensland Carboniferous beds. The writer has held the view that it might be Neerkol, and this has been strengthened considerably by Dr. Whitehouse's remarks.

J. H. Reid (1930) advocated an Upper Carboniferous age for the Jump-Up Hill beds on the evidence of the fossils collected by Andrews. It is hoped that the additional forms which have been collected will be of assistance in the determination of the exact age of the Series.

Though Fenestellidae zones are not uncommon in Carboniferous and Permian areas, the presence of the prolific band near Jump-Up Hill lends more support to a correlation with the Neerkol beds.

The writer is still opposed to the inclusion of any part of the Kempsey or Silverwood beds in the Neerkol, and consequently cannot agree to placing any of the beds belonging to the Drake Series there (Voisey, 1934*a*, 1935).

Drake Series.

Taken as a whole the fossil fauna of the Drake Series is as follows:

Cladochonus cf. *tenuicollis* McCoy.
Trachypora wilkinsoni Eth. fil.
Monilopora cf. *nicholsoni* Eth.
Zaphrentis gregoriana De Kon.
Cyathocrinus (?).
Phialocrinus (?).
Protoretepora ampla Lonsdale (?).
Fenestella sp.
Fenestella fossula.
Fenestella internata.
Penniretepora grandis.
Hyalostelia.
Stenopora tasmaniensis Lonsdale (?).
Strophalosia gerardi.
Strophalosia cf. *jukesi* King (?).
Martiniopsis subradiata var. *deltoidea* Eth. fil.
Spirifer spp. mult.
Spirifer stokesi Konig.
Spirifer vespertilio.
Productus undatus (?).
Taeniothaeris subquadrata.
Productus brachythaerus.
Myonia carinata Morris.
Myonia (?) *corrugata* Fletcher.
Stutchburia compressa.
Astartila sp.
Deltopecten subquinquelineatus McCoy sp.
Aviculopecten sprenti Johnston.
Aviculopecten englehardti Eth. and Dun.
Aviculopecten cf. *flexicostatus* Mitchell.
Aviculopecten squamuliferus Morris.
Aviculopecten elongatus McCoy (De Kon.).
Hyalostelia.
Entolium.
Modiola.
Orthoceras.

All these forms were found in, or above the volcanic rocks, so must be above the *Glossopteris* horizon which occurs below the Volcanic Beds at Silverwood, if correlation between the lavas is accepted.

Conclusive proof of the existence of prolific *Monilopora* cf. *nicholsoni* and *Trachypora wilkinsoni* beds at the top of the Series definitely overlying the volcanic beds, has an important bearing on the interpretation of the Silverwood fault-blocks. (Richards and Bryan, 1924; Reid, 1930; Voisey, 1935.)

It is unfortunate that a *Eurydesma cordata* horizon was not found in the Boorook-Drake Districts, but, if the views of the writer are correct, this should be discovered below the Volcanic Series (Voisey, 1935).

In a broad sense the Silverwood Fault Block Series, the Drake Series and the Macleay Series are correlated with one another and all are considered to be Lower Permian in age.

Structural Geology.

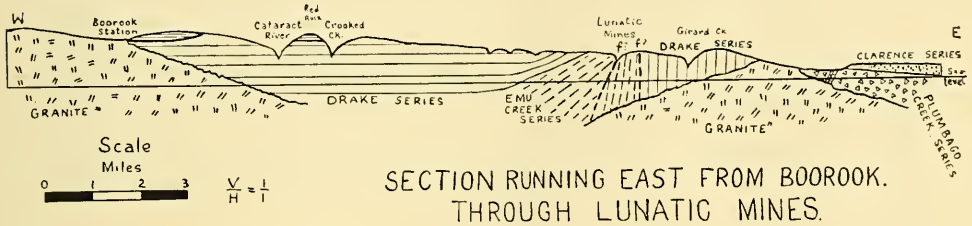
The Upper Palaeozoic strata are generally horizontally disposed or slightly undulating between the western granite and Drake, but between Drake and Tabulam they have been folded and faulted. In the Drake Series near Tea-Tree Creek, a vertical position has been attained. At the bridge where the road crosses the Creek, the unconformable junction of an outlier of the Clarence Series with the volcanic beds may be seen.

The folding has been roughly on a north-north-west, south-south-east axis.

The old Boorook township site is in the core of a syncline which pitches towards the north. It is a very gentle fold. The beds on the limbs of the syncline dip into the hill at angles generally about 5°. The northward pitch is demonstrated by the outcrop of the mudstones. This is roughly V-shaped, widening to the north.

Wherever rocks belonging to the Emu Creek Series have been seen they are steeply folded, but this may be because the disturbed zone happens to include them. Nevertheless, the conformity of the Emu Creek Series and Drake Series is open to doubt.

Going westward from Jump-Up Hill along Emu Creek the beds dip west at angles between 40° and 60°, but here and there they are much faulted.



SECTION RUNNING EAST FROM BOOROOK. THROUGH LUNATIC MINES.

A parallel might be drawn between the Drake and Kempsey Districts. In both cases there are areas of intense folding of Upper Palaeozoic beds to the east and gently folded beds to the west. It seems that pressure came from an easterly direction. The marginal beds yielded to the force and, by collapsing, allowed it to expend itself on them, thus protecting the strata to the west.

The New England granite was intruded into the Drake rocks after the folding had taken place. It cuts across the strike of the beds. This was some time before the Jurassic sediments were deposited, for these rest upon planed-down granite surfaces. That the diastrophism occurred between Middle Permian and Jurassic times is thus proved, but in all probability it marked the close of the Palaeozoic Era (David, 1932).

Richards and Bryan (1924) offered the suggestion that the "Permo-Carboniferous" fossils collected in the Drake District might have been obtained from isolated fault blocks let down into Devonian strata, the structures then resembling those at Silverwood. However, no rocks remotely related to the Silverwood Series (Devonian) were found in the area examined and the volcanic units were found to be continuous for many miles.

The sediments belonging to the Clarence Series formerly covered a much greater area west of their present boundary, but they have been removed by erosion. An outlier at Kettle's Lift remains, and this is being worn away rapidly.

The beds dip easterly at a very low angle and form the western rim of the Clarence Basin.

Physiography.

Boorook and Drake are situated on the eastern fall of the New England Tableland near the head-waters of the Clarence River.

The Cataract River collects Boorook Creek, Crooked Creek, and numerous tributaries as it flows northward from Sandy Hills to Rivertree, where it joins

the main stream. The Clarence turns southward and eventually reaches Tabulam where it collects the drainage from Drake which enters it by means of Plumbago Creek and the Timbarra River.

The dissection which has occurred may be judged by the steep fall of the country from Tenterfield just west of the Main Divide to Tabulam. The heights are: Tenterfield, 2,831 feet; Drake, 1,650 feet; Tabulam, 410 feet.

Between Tenterfield and Boorook high granite hills rise to over 3,000 feet and continue northwards as the Boonoo Boonoo Heights. East of Boorook Station the creek falls into the Cataract which flows through narrow gorges carved out of the resistant lavas of the Drake Series. Both this river and its tributary, Crooked Creek, are aptly named. Travelling is difficult through this region, but access may be had by means of tracks which follow the more gentle spurs.

The response of the sub-horizontal rocks to rapid erosion is the main feature of the physiography, and both the Clarence Series and the Drake Series (in part) may be studied in this connection. The Clarence Series occupies the lower regions, and cliffs are formed where the hard sandstone beds alternate with softer slates. These are common on all sides but the east, as the dip of the units in this direction is sufficient to give rise to a dip-slope. As a great deal of the country has been cleared, these sandstone bluffs make conspicuous features as they rise above the undulating grassy areas and usually a number of trees remain on them. Sometimes two bands may be seen in the one hill.

The big difference in resistance to erosion between the lavas and sediments of the Drake Series has led to the development of benches round the hills.

As the streams have cut down into the Lower Division, the fossiliferous beds of the Upper Division occupy the ridges between the valleys. The natural contouring of the highlands by means of these resistant bands is somewhat obscured by the thick vegetation. Along the stock route between Sandy Hills and Drake, one goes from terrace to terrace. On some of these terraces, outliers of the overlying bed form small hills. One unit in particular, an agglomerate from the top of the Lower Division of the Drake Series, gives rise to such outliers since it is underlain by a resistant tuff band.

Between Cheviot Hills and Emu Creek the topography is neither so interesting nor is its evolution so clear. Outcrops are poor, and in the north the rocks are similar in type and dip steeply. Here deep gullies, tending to conform with the strike, lead into the main creek and the spurs fall steeply into them.

In the south-eastern corner of the area the old granite surface upon which the Clarence Series was laid down has been re-exposed during recent times and the streams are at work cutting downwards into it.

The sequence of events leading up to the formation of the present topography is similar to that of the whole coastal region, and the matter has been discussed elsewhere. (Craft, 1933, etc.; Andrews, 1903; Voisey, 1934).

Geological History.

Marine mudstones, sandstones and conglomerates were deposited, during Carboniferous times, in a sea which had its location in the position now described as north-eastern New South Wales. Rhythmic deposition was a characteristic feature of this thick series of rocks.

With the beginning of Permian times, vulcanism broke out and volcanoes which were situated in the region about Drake poured lavas over the sea-floor.

Tuffs and mudstones were laid down between the lava-flows and in these sediments the remains of marine animals were preserved. Eventually the activity of the volcanoes declined, and a thick deposit of mudstone was spread over the sea floor.

Pressure from the east affected the sediments, some of which yielded under the strain, fracturing and folding taking place in some areas; but the western portions were protected and remained practically horizontal. The invasion of the rocks by granite followed, metamorphosing them and introducing the auriferous, cupriferous and argentiferous quartz-reefs. Uplift and subsequent erosion led to the exposure of the granite and the reduction of the area to comparatively level country over which an inland sea transgressed during Jurassic times. Fresh-water conglomerates, sandstones and shales were laid down, and among them were preserved the logs and plant remains washed in by the rivers.

Eventually the sea receded and uplift brought the Clarence Series under the influence of erosive forces which reduced Eastern Australia practically to sea-level, leaving only a low divide. Basalts were poured out over this surface. Uplift occurred at the end of the Tertiary Era and subsequent erosion has led to the development of the present-day topography.

Conclusion.

The most outstanding results obtained from the field-work in the Drake and Boorook districts are as follows:

(1) The Drake volcanic beds have been separated from the Jump-Up Hill beds and the basis for such separation has been given.

(2) Suites of fossils were collected from each series and arranged in their correct stratigraphical positions.

(3) The relationship between the Boorook and Drake rocks was determined beyond doubt.

(4) A zone extraordinarily rich in *Trachypora wilkinsoni* and *Monilopora* cf. *nicholsoni* was proved definitely to overlie the volcanic beds of the Drake Series.

It is hoped that the data collected will be useful to palaeontologists and to future workers in a most fascinating locality.

Acknowledgements.

I desire to thank Dr. Ida Brown, of Sydney University, Mr. Fletcher, of the Australian Museum, and Dr. F. W. Whitehouse, of Queensland, for their notes upon the fossils. I am indebted also to Messrs. T. Hodge-Smith and R. O. Chalmers for their capable work in cataloguing the material which I have given to the Australian Museum.

Geological work at Drake, Boorook and Tabulam has always been a pleasure—largely because of the help and hospitality given to me by numerous residents. My grateful thanks are due to them, especially to the following: Mr. and Mrs. Arthur Smith of Cheviot Hills, Mr. and Mrs. Clarence Smith of Boorook, Mr. and Mrs. Hunter Smith of Drake, Mr. G. Purvis Smith of Sandy Hills, Rev. Schmitzer and Mr. and Mrs. Fergusson of Tabulam.

Bibliography.

ANDREWS, E. C., 1903.—The Tertiary History of New England. *Rec. Geol. Surv. N.S.W.*, vii, pt. 3.

————, 1905.—Geology of New England Plateau. *Rec. Geol. Surv. N.S.W.*, viii.

————, 1908.—Report on the Drake Gold and Copper Field. *Geol. Surv. N.S.W., Mineral Resources*, No. 12.

BROWNE, W. R., 1929.—An outline of the History of Igneous Activity in New South Wales till the close of the Palaeozoic Era. PROC. LINN. SOC. N.S.W., liv.

CRAFT, F. A., 1933.—The Coastal Tablelands and Streams of New South Wales. PROC. LINN. SOC. N.S.W., lviii.

DAVID, T. W. E., 1932.—Explanatory Notes to a New Geological Map of Australia.

JAQUET, J. B., 1896.—Report on the Lunatic Goldfield. *Ann. Report Dept. Mines and Agriculture, N.S.W.*, pp. 126-128.

REID. J. H., 1930.—The Queensland Upper Palaeozoic Succession. *Queensland Geological Survey Publication*. No. 278.

RICHARDS, H. C., and BRYAN, W. H., 1923.—Permo-Carboniferous Volcanic Activity in Southern Queensland. *Proc. Roy. Soc. Queensland*. xxxv.

————, 1924.—The Geology of the Silverwood-Lucky Valley Area. *Proc. Roy. Soc. Queensland*, xxxvi.

SUSSMILCH, C. A., 1935.—The Carboniferous Period in Eastern Australia. *Report A.N.Z.A.A.S.*, Vol. xxii.

VOISEY, A. H., 1934*a*.—A Preliminary Account of the Geology of the Middle North Coast District of New South Wales. PROC. LINN. SOC. N.S.W., lix.

————, 1934*b*.—The Physiography of the Middle North Coast District of New South Wales. *Journ. Roy. Soc. N.S.W.*, lxviii.

————, 1935.—An Interpretation of the Silverwood-Lucky Valley Upper Palaeozoic Succession. *Proc. Roy. Soc. Queensland*, xlvi. 1934 (1935).

WALKOM. A. B., 1913.—Stratigraphical Geology of the Permo-Carboniferous system in the Maitland-Branxton District. PROC. LINN. SOC. N.S.W., xxxviii.

EXPLANATION OF PLATE VIII.

Geological sketch-map of the Boorook-Drake district.